Measuring Polariton-Polariton Interactions with Multidimensional Coherent Spectroscopy

M. Berkman[1,*], J.O. Tollerud[1], E. Estrecho[2], K. Winkler[3], M. Kamp[3], C. Schneider[3,4], S. Höfling[3], E. A. Ostrovskaya[2], J. Davis[1]

[1]Optical Sciences Centre, Swinburne University of Technology, Victoria 3122, Australia
[2]Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National University, Canberra, ACT 2601, Australia
[3]Physikalisches Institut, Universität Würzburg, 97074 Würzburg, Germany
[4]Institut of Physics, University of Oldenburg, D-26129 Oldenburg, Germany

Experiments that measure the interactions between exciton-polaritons have been performed in the past [1,2], but are frequently met with challenges around precisely quantifying the polariton density and the presence of excitons. Here, we utilise 2D electronic spectroscopy to quantify polariton-polariton interactions in a Gallium Arsenide microcavity/quantum well system. With this approach we are able to directly excite the polaritons, with a well-defined density, and in the absence of any excitons. It also allows control of the polarization, meaning we can selectively excite polaritons of the same angular momentum to quantify the same-species interactions, or isolate interspecies interactions with cross-circularly polarized pulses or a mixture with linearly polarized pulses.

From the 2D spectra, such as those shown in Fig. 1, we are able to measure both a blue-shift and linewidth broadening as a function of density, allowing us to determine the real and imaginary parts of the interaction strength, for different detunings. The polariton densities are determined based on the energy absorbed from each laser pulse, and confirmed through the relationship between the measured blueshifts and broadening. Measurements over a range of excitonic fractions of 0.49-0.76, lead to interaction strengths between same-spin polaritons similar to those obtained in [1]. For the interactions between polaritons with opposite spin, the values we observed were 3-7 times smaller than the same spin interaction strength, which is larger than expected from previous works [3,4,5].

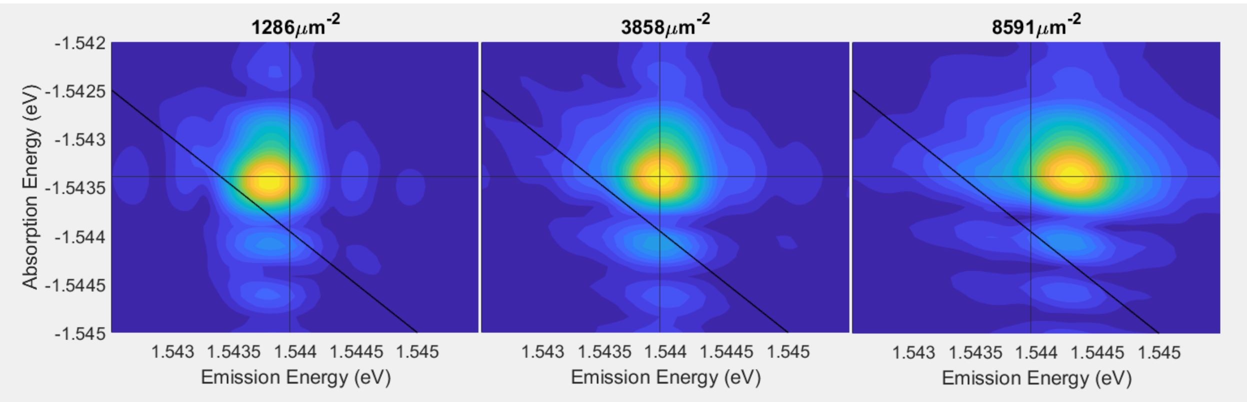

Figure 1: Set of 2D plots obtained over a range of polariton densities via MDCS measurements. As the density increases there is a clear blueshift and linewidth broadening in the Emission (E3) energy which is proportional to the real and imaginary components of the interaction strength respectively..

References

[1] E. Estrecho et al., “Direct measurement of polariton-polariton interaction strength in the Thomas-Fermi regime of exciton-polariton condensation”, Physical Review B 100, 35306 (2019).
[2] Y. Sun et al. “Direct measurement of polariton–polariton interaction strength”, Nature Physics 13, 870–875 (2017).
[3] M. Vladimirova et al., “Polariton-polariton interaction constants in microcavities”, Physical Review B - Condensed Matter and Materials Physics 82 (2010).
[4] N. Takemura et al. “Heterodyne spectroscopy of polariton spinor interactions”, Physical Review B 90, 195307 (2014).
[5] D. Biegańska et al., “Collective Excitations of Exciton-Polariton Condensates in a Synthetic Gauge Field”, Physical Review Letters 127, 185301 (2021).

*Email: mberkman@swin.edu.au